Developing Global Teamwork Skills: The Runestone Project

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Abstract— **The Runestone project is a collaborative course currently offered by Universities in Sweden, Finland, and China. The course provides a unique opportunity for third year engineering students from a variety of programs to experience the opportunities and challenges that international teamwork involves. Teams composed of students from two countries work intensively over a 10 to 13 week project cycle to develop a system which allows a user to remote-control a LEGO NXT robot. The teams negotiate the features of their final system with the academic supervisors from the participating Universities, propose a development time-frame and deliverables, and develop and demonstrate a prototype system.**

This paper uses teaching and learning findings from engineering education research. The evidence is used to arrive at an instructional design that aligns learning outcomes, with instruction and assessment to support student's learning outcomes development throughout the course, We also discuss the evolution of the course over the past 12 years as we moved from a pilot version with eight students from two universities to a large scale course with between sixty and eighty students from between three and five universities distributed over three continents and widely different educational and social cultures.

Keywords— **engineering skills, educating the global engineer, global virtual teamwork**

I. Learning Outcomes and Motivations

The quality of engineering education, and the relationship of curricula to competencies valued by industry, is increasingly important as the world moves towards a more student centric and socially relevant style of education [1]. Quality assurance of outcomes is also an important driving force, as many nations transform their education in response to the Bologna process [2]–[6]. One important element in the learning trajectory from novice to expert is experiencing the uncertain nature of problem solving in a loosely constrained environment.

Some common features of professional work that are seldom represented in University classrooms and practical exercises are associated with the more open ended problem specifications that can arise. Equipping students with a range of important professional skills, such as project management, teamwork and cross-cultural communication can be achieved in a carefully managed open ended project course.

Industry problem specifications are often stated in rather fuzzy high level terms. An open problem specification places different demands on learners than traditional practical work or course assignments. The course we describe in this paper scaffolds learners' development in a number of aspects of professional working practice. During the course we mentor students through the analysis of the problem space and proposal of a feasible solution, identification of appropriate tools and techniques with which to solve the problem, managing and working in a team, and learning about working with people from different cultures.

The objectives of the Runestone course are to give students experience with a problem and work situation which requires them develop a greater level of self-reliance, teamwork, negotiation and communication skills, integrate and use theoretical knowledge from earlier courses, and (through experience of a wider systems development project cycle) understand that the theories we teach in subjects like software engineering are not prescriptive and do not always lead to timely delivery and successful products.

Through the Runestone project we provide students with significant and valuable experiences, directly relevant to their future working life, while retaining some of the benefits of a "safe" educational environment. By "safe" we mean that students can experiment with applying their theoretical knowledge to a systems development task in a supportive environment where they do not risk losing their job, or failing the course. Students are not, however, left to "sink or swim", active bi–weekly mentoring meetings (Milestones) are used to support and guide students as they struggle to develop the skills they need.

The assessment criteria are designed to stimulate and reward students who engage in processes and activities that contribute to their development of insight and skills for dealing with the realities of systems development in a globally distributed virtual team environment. This means that a student can complete the course, and gain a pass, even if the system they deliver falls short of achieving the functionality and quality required to release a product. Passing the course depends much more on working processes and sincere attempts to put theory into practice, than it does on developing a successful and robust hardware/software system.

II. RUNESTONE

Research on designing learning situations that help develop professional engineering skills such as teamwork, cultural awareness, and project management is a key area as we design programmes to educate the next generation of engineers. Grandin et al. [7] identify a number of key areas in a recent report where they call for action to address the needs of future engineers. Part of our approach to addressing these educational challenges in the IT programme at Uppsala University is the "Runestone Project", a collaborative course in engineering systems development spanning multiple Universities and cultures. [1] Runestone is based on the well publicised idea of providing motivation and scaffolding for the development of professional skills through open ended group project work [8], [9]. This paper provides an overview of the models [10], [11] educational theory behind the course design and an overview of its current structure. One unique aspect of this course is that is has been offered continuously over the last twelve years, expanding from a pilot course with a single group of students to a full scale collaborative course with 60 to 80 students participating from four nations.

Runestone students complete a team role and skills evaluation exercise at the start of the first week of the project and are subsequently placed into teams by the instructors. Teams have approximately six members from two sites, and are supervised by an instructor from the teaching team, with whom they have regular virtual meetings throughout the course. Assessment and mentoring of the teams occurs in the virtual meetings. Staff and students do not meet physically very often during the course, indeed many of the students might be in another country than the staff member supervising their team.

The course requires students to design and implement a large scale distributed system. The task is closely related to a realistic engineering work assignment [12], and requires knowledge of many aspects of their previous study in distributed systems and network programming. The course provides students with experience of team based product development, in a modern technical work environment where teams are both culturally diverse and geographically distributed.

The course combines application of technical skills with other important global engineering skills: teamwork; negotiation and project planning; and project execution.

Technical

In recent years teams have developed a software system to give users remote control of a robot, build using LEGO NXT, in a location anywhere in the world via the Internet. The project used in the early years was based on custom built hardware. However, maintaining and coordinating acquisition of these systems for all the collaborating sites became too complex after a few years, and we replaced the custom hardware with LEGO Mindstorms robots in 2003. A further transition to LEGO NXT hardware in 2007 was motivated by difficulty of obtaining the, now obsolete, Mindstorms RCX hardware. Wear and tear on the LEGO RCX kits, and the availability of bluetooth communication in the LEGO NXT, replacing the infra-red communication used in the first Mindstorms platform, were other reasons for the change.

The specification has undergone several revisions over the twelve years we have been running the project, but the salient characteristics and their relationship to learning outcomes and assessment policies has remained largely unchanged over the last ten years. The project has a ten to thirteen week timeframe. The activities and deliverables for 2005 shown in 1 are typical. There are slight timetabling variations from year to year depending on the level of synchronisation of the academic timetables at the participating sites.

The current task requires teams to design and implement a software system which allows a remote user to control a LEGO NXT robot (of their own design) in real-time through a web browser Graphical User Interface (GUI). Communication between the robot and server is implemented using the BlueTooth wireless communication protocol. Communication between the server and GUI can be implemented in a variety of technologies. Since a real-time video stream of the robot environment is to be incorporated in the GUI some low level network programming using sockets and the UDP and TCP protocols is also required.

Teamwork

Teamwork and the process of collaboration is closely observed during the project and the teams are required to report regularly. Regular mentorship is a key element of the course [13] and helps the teams to negotiate a range of issues that arise from the technical challenges and personal and cultural differences. Active and regular mentorship feedback is a crucial element of the learning activity in the course, providing information and helping students to negotiate the technical and personal crises that arise naturally during the course.

Development of written communication skills is facilitated through critique of the design documents and bi-weekly reports the teams present. Each report is presented using online synchronous chat, this allows the instructors to evaluate team member's communication skills and ability to organise and use time effectively. The instructors also observe the internal social dynamics of the team, and provide feedback and advice.

Process Management

Problem analysis and specification documents are requested early in the project and critiqued, each deliverable, including documentation, verbal presentation and collaboration processes are incorporated in the final team grade. Teams are also asked to provide an implementation timeline in the form of a "Gantt Chart", in which the major sub-project dependencies should be identified. Instructors use this chart to assessing the team's ability to make progress, estimate time requirements, and adjust work-flows as time mis-estimations become apparent during the project.

[1] The course is a collaboration between Uppsala University, Sweden, Grand Valley State University, USA, Rose-Hulman Institute of Technology, USA, Tongji University, China, and Turku University, Finland.

Project Week	2005 Dates	Activity
0	9-13 Jan	USA Only: Intro
1	16-20 Jan	Intro and Team Building
		Course begins 19/1 in Sweden
2	23-27 Jan	Work on Team Building experience (no IRC[2] meeting this week)
		Prepare Web site and CVS for team
		Work on Analysis and Design
3	30 Jan -03 Feb	Milestone 1: Present Team Web Site(IRC report)
		Present Individual Team members and their profile pages
		Work on Analysis and Design
4	06-10 Feb	Milestone 2: Present Analysis and Design Docs (IRC)
		These deliverables are marked contributing 10 marks
		to the final group grade
5	13-17 Feb	Continue work (no IRC meeting this week)
6	20-24 Feb	Present Milestone 3 (IRC report)
7	27 Feb-03 Mar	Work on project sub-system integration
		Prepare your final presentation materials
8	06-10 Mar	Spring Break in the USA. Sorry Swedes!
		Teams work informally, maybe mostly in Sweden?
9	13-17 Mar	Present Milestone 4 (IRC report)
10	20-24 Mar	Final Presentations

Fig. 1. Project timeline

Instructional Approach

Few resources are provided initially. Students are expected to locate and make choices of the software and operating system to use with the LEGO NXT processing unit, as well as communication protocol stack to handle communication between their software system and the robot. We provide links to some appropriate software, but nothing is specified in the project description. The instructors assess the technical learning outcomes based on the level of sophistication of the software and the complexity of the attempted functionality, as well as the degree to which the software is complete and working at the end of the project.

Development and assessment of skills such as teamwork and intercultural communication are based on continuous online mentoring and discussion in the regular virtual meetings throughout the course. Assessment of outcomes is based on observation of how the teams deal with communication and work process issues in the presence of tight deadlines and high workloads.

Managing this process for a team of instructors also presents challenges. To make judgment of skills and deliverables comparable between instructors the teaching team have regular online meetings, and discuss the interpretation and application of the qualitative grading criteria (see figures 2 and 3 for examples of some of these grading rubrics). Many of the larger deliverables are assessed by several instructors, for instance the design documents and final presentations are usually assessed by the instructors for both the sites involved in each team. Finals marks are discussed if there is a difference of opinion between two instructors. Our experience is that instructor agreement rates are very high, we have never had serious disparities or disputes over marks for design documents or final presentations.

A key element of the Runestone approach is the course assessment framework. Our assessment structure focuses on aspects of the project work including technical achievement, work process, teamwork, and communication and cultural sensitivity which are vital to future practicing engineers. In the following section we examine some aspects of the course structure and assessment activities in more detail.

III. Assessment

The project work-flow and deliverables used to assess teamwork and software development processes are summarised in figure 1. The dates given here are for the 2005 academic year and provide a guide to how the sequencing of courses was managed between Sweden and the USA. Coordination between Sweden and participants in China and Finland is easier as students from the participating universities have had greater flexibility in their study timetables.

Assessment is based on a combination of individual and team achievements in a range of areas. The goal is to provide motivation for students to engage in both the technical and non-technical aspects of the project in order to achieve the desired learning outcomes. Assessment is divided into three primary areas.

Teamwork and Communication :
evaluating the organisational ability of the team and the manner in which the team presents itself and works as a unit to achieve its goals. This includes individual marks for those elements of the reporting for which individuals are responsible, as well as peer

Grade	Classification	Qualitative criteria
0	Missing	No report from group
1	Inadequate	Poorly structured, several required areas missing or incomplete, some material not online prior to the meeting.
2	Poor	Poor to adequate structure of material. some required data missing or hard to find. Confusing presentation and layout of pages hard to read.
3	Adequate	All required information is presented and adequately organised, however, layout and structure make it hard to evaluate the accomplishments of the team since the last report.
4	Fair to Good	All information is supplied and structured according to the reporting requirements. Some areas of the report do not give sufficient relevant information for the reader to assess the progress of the team and the individual contributions of the members since the last milestone.
5	Excellent	All information is supplied in a format and structure that is consistent with the reporting guidelines for the course. Information content is relevant, concise and gives a clear and accurate impression of all aspects of the achievements of the group and individuals within the group since the preceding milestone.

Fig. 2. Criteria for awarding team grades at each project Milestone

evaluation of the contribution of each member by the other members of the team (at the conclusion of the project).

Project Management:
evaluating the interim progress reports and the online meetings in which the team reports on progress. Assessment here focuses on the ability of the team to plan realistically and work towards reaching the milestones they have defined.

Technical Achievement:
evaluating the complexity of the milestones the team set, and the levels of technical achievement reached during the product development process. Assessment is based on professional code development and the sophistication of the final product.

Contributions by individuals and teams in each of the assessed areas are evaluated throughout the course using the following deliverables. There is no written final examination in the course, deliverables in all projects are evaluated throughout the course, and the final project demonstration plays a significant role in determining the final grade. Individual grades are based on the group grade, to which modifiers are applied based on peer and instructor assessments of individual contributions to the project development and ultimate success.

A. Teamwork and Communication (30 points):

- Milestone Meetings (20 points)
  There are four milestone meetings, and at each of these the teams gain between 0 and 5 points depending on the performance of the group. This gives a total of 20 points. After each meeting an online critique of the meeting and report is made available to the team immediately via private pages on the course Wiki. The critique provides written feedback on the presentation, as well as the assessment of the instructor (in the form of a grade on the 0-5 scale).
  The qualitative associations we use to allocate a grade on the five point marking scale are shown in figure 2.
- Individual Achievement (10 points)
  At the end of the course, each individual's contributions to the meetings, and their level of engagement in the project are graded.
  A mark of 0 to 5 is be allocated by the teaching staff on the basis of their assessment of each individual's contribution to the project in terms of attendance and participation in group meetings, and contribution to team spirit and success.
  A further mark of 0 to 5 is be awarded on the basis of the peer reviews of each team member by their teammates. This gives the remaining 10 points in this category. We have studied how students approach the anonymous peer review [14]. In our experience this aspect of the course works well, and students typically give a balanced and responsible assessment of the contributions of the

Max. Points	Criteria
5	Research an area and write-up a report describing what you learned
6	Research an area and include that research in the design document
8	Research an area, include it in the design document, and create a working prototype apart from the project itself
10	Research an area, include it in the design document, integrate it into the project

Fig. 3. Grading criteria for Areas of Excellence

individuals in the team.

B. Project Management (30 points):

The **team progress grade** reflects the extent to which the team has demonstrated good project management practice in their workload allocations and priority setting.

A mark from 0 to 10 is awarded on the basis of the quality of the project analysis and project specification documents prepared by the team.

The remaining twenty marks are earned during the project based on the extent to which the team has achieved its self defined goals for milestones three and four. This mark is based on the demonstrated achievements of the team being consistent with the expectations stated in their development and implementation plan.

C. Technical Achievement (40 points):

Twenty (20) marks are awarded for the final presentation and the product demonstration. Criteria for assessing final presentations are included as appendix A. Two instructors are two teams participate in every one hour video conference presentation slot. The teams make a presentation of their development process, and reflect on their project and what they have learned. Each presentation concludes with a live demonstration of the software, and questions from the other team.

The tools we have used for video-conferencing in the final presentations have varied considerably. In early courses we used a combination of Microsoft NetMeeting. Later versions of the course used either Skype or Marratech. In 2010 we will use Adobe Connect.

Another twenty (20) points are for technical innovation and high quality technical achievements in two nominated areas of “excellence”. As a part of setting milestones or goals, the teams will be asked to identify two areas of the product where they intend to aim for advanced development leading to “excellence” in the resulting technical solution. Marks are allocated in these areas according to the guidelines in figure 3.

Conclusions and Future Work

The Runestone project approach has been incrementally refined over the last twelve years to provide students with global teamwork experience in a realistic project setting. The course has expanded to involve universities outside the original partnership, and now involves up to four universities and between sixty and eighty students annually.

The main contributions of the current paper are to completely describe the current structure and assessment strategy for the course and link this to learning outcomes in communication skills, global teamwork, and virtual collaboration. By publishing this course model we contribute to a growing literature on the use of open ended project work in preparing students to work effectively in the workplaces of the future.

Appendix

A. Presentation Grading Scheme

3pts Professionalism in preparation and presentation.

1) Was the team well prepared and organised.
2) Smooth and well rehearsed presentation structure.
3) Use of presentation tools (IRC, NetMeeting, hardware demo)

5pts Use of web and audio-visual presentation technique.

1) Was material clearly presented and easy to understand. (i.e. pictures, good slides, etc.)
2) Is the presentation clear, to the point
3) Does the presentation show off the whole team, and each person’s accomplishments/contributions.

5pts Team Management

1) Division of labor
2) Leadership
3) Time and scheduling difficulties
4) Personality conflicts

5pts Technical Discussion and Demo

1) Design process
2) Coding standards, version control, software management issues
3) Software package and documentation standards
4) Limitations and future enhancements
5) Demonstrated software functionality

2pts Question and Answer

1) Posing good questions to the other team.
2) Responding well to questions from others.

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